

Data Analyses

We used analysis of variance (ANOVA) to compare habitat parameters at successful and unsuccessful nests using a Bonferonni correction for repeated one-way tests. We set our rejection level (i.e., α) at $0.05/12 = 0.004$. Data derived from circular distributions (e.g., burrow entrance orientation, dispersal direction) were analyzed using circular statistics (Zar 1984). Mean angles (α) and angular deviation (s) were calculated for each sample, and a mean vector was plotted. The length of the mean vector (r) ranges from 0 - 1 and varies inversely with the amount of dispersion in the data. For example, $r = 1.0$ when all data are concentrated in the same direction, and $r = 0$ when there is so much dispersion that a mean angle cannot be described. We used Rayleigh's test to examine the null hypothesis that the population is uniformly distributed around the circle (i.e., in all directions). We compared mean angles between different groups using the Watson-Williams test (Zar 1984).

RESULTS

Trapping and Banding

Between 15 May and 14 August 1994, we captured 71 burrowing owls, including 7 adult males, 16 adult females and 48 juveniles. Appendix A contains band numbers, banding dates, color band combinations, radio transmitter frequencies, and age and sex information for owls captured during this study. Using a variety of methods (Table 1), owls were captured at or near 19 different nest burrows. Most nests were located on BLM land (Fig. 1). Most adult females were captured using Havahart® live traps while incubating eggs or brooding young. Adult males were more difficult to capture than females because they rarely entered nest burrows. The males that we did capture were caught using bal-chatri traps baited with a live mouse, noose rods, and Havahart® live traps. We captured many juveniles with noose rods and noose carpets buried at burrow entrances. As juvenile owls emerged from their burrows by walking along the entrance, they became entangled in the monofilament nooses extending from these traps. We also captured young owls ($N = 8$) by hand at entrances to burrows before the young could escape into burrows (Table 1).

Nest Site Habitat

We measured habitat parameters at 14 nests within the study area (summaries of habitat data sheets are provided in Appendix B). Burrowing owls nested in open areas, such as grasslands, with low vegetation. Vegetation at nest burrows averaged slightly more than 10 cm in height but increased to approximately 20 cm when averaged within a 2 m distance of nests (Table 2). Burrowing owls are thought to prefer low vegetation in the vicinity of their nests to facilitate detection of mammalian predators that could more easily approach nests in tall, dense vegetation. Most nests we studied were located in areas previously dominated by

dense big sagebrush that had burned within the recent past (within 7 years). The area has subsequently converted into grasslands, dominated by cheatgrass brome and tumble mustards (*Sisymbrium* spp.), with a few big sagebrush trunks remaining. The vegetation around 10 nests (71.4%) was dominated by a mixture of cheatgrass brome and tumble mustards. The remaining four nests were surrounded by a mixture of cheatgrass brome, tumble mustards, and big sagebrush.

Nest burrows were characteristic of those dug by badgers (*Taxidea taxus*) and yellow-bellied marmots (*Marmota flaviventris*), and burrow availability within the study area appeared high enough that this factor would not limit reproduction by owls. Livestock manure was readily available because of the nearby dairy farm, and all nesting burrowing owls gathered manure to line the nest burrow or entrance. On average, active nests had another suitable burrow within 15 m, and there was an average of slightly over 4 additional burrows within a 10 m radius circle centered on nests burrows (Table 2). Table 3 illustrates the pairwise distances between 13 nests examined during 1994. The average orientation of burrow entrances was $93.9^\circ \pm 65.5^\circ$ (mean \pm angular deviation; $r = 0.346$) as illustrated in Fig. 3. We were unable to reject the null hypothesis that the population of burrow entrances is uniformly distributed around the circle (Rayleigh's $R = 4.84$, $z = 1.673$, $P > 0.10$). Thus, the sample of burrow entrances is not significantly oriented in a particular direction.

Burrowing owls used perches near their nests to scan for predators and prey, and to roost upon. Perches included metal fence posts, rock piles, dead sagebrush, a man-made shooting stand, manure piles, dirt berms, and wood fence posts. The nearest perch to each nest was an average of 13.4 m away, and perches averaged approximately 1 m in height (Table 2). Nests were typically close to (e.g., within 100 m) of agricultural fields (often used by owls for hunting prey), paved or gravel roads, and a source of water (Table 2).

Comparison of Habitat at Successful and Unsuccessful Burrows. — We defined successful nests as those that fledged at least one young owl. In 1994, eight nests successfully fledged young, while six were unsuccessful. To determine if nesting habitat affected reproductive success, we compared habitat parameters at successful and unsuccessful nests using separate univariate analyses of variance (ANOVA). Successful nests had lower vegetation both at the burrow entrance and within 2 m, but none of the univariate F-tests was significant (Table 4). Additionally, orientation of burrow entrances did not differ between the two groups (successful: $90.5^\circ \pm 60.7^\circ$, $r = 0.440$; unsuccessful $102.8^\circ \pm 71.4^\circ$, $r = 0.223$; Watson-Williams test: $F_{1,12} = 0.044$, $P > 0.50$; Fig. 3). However, before one can conclude with confidence that these and other habitat parameters did not affect reproductive success, a much larger study is required. Given the amount of variation in many of the parameters we examined, much larger sample sizes from longer term studies would be required to detect differences if in fact they occurred (i.e., to avoid type II statistical errors).

Breeding Season Behavior

We developed a chronology of breeding season activities based on our observations during the 1994 field season. Figure 4 indicates the timing of adult arrival, incubation of eggs, hatching, brooding, fledging, post-fledging dispersal, and fall migration. Below we review burrowing owl behavior during the pre-fledging and post-fledging periods, and provide an indication of the timing of fall migration based on observations of radio-tagged adults and juveniles.

Pre-fledging Behavior. — During the incubation and brooding periods (late-April to mid-June), adult male burrowing owls often remained close to nest burrows, either perched at the burrow entrance or on a nearby perch. Roosting males were vigilant, and they typically vocalized upon our approach. Males uttered their characteristic alarm call, at which time they flew to a nearby area to observe our activities around the nest burrow. Adult females typically remained in nest burrows either incubating or brooding young during the pre-fledging period. We observed adult males only rarely entering nest burrows. Males often left prey items at the burrow entrance, at which time adult females emerged and took the food items to their young within the burrow. Thus, our observations indicate that during the pre-fledging period adult males actively hunt and provide food for their mates and offspring. Adult males perched near the nest burrow and remained vigilant for potential predators and, via vocalizations, they perhaps communicated impending danger to females, who were frequently beneath the ground. Adult females appeared to incubate eggs without the assistance of their mates (only females developed brood patches), and females conducted the majority of the brooding of young.

Most juvenile burrowing owls hatched between mid-May and early-June (Fig. 4). The first young owls appeared above ground on 20 May. Based on morphological and feather development, we estimated that juveniles were typically around 10 - 12 days old when they appeared at burrow entrances for the first time. Juvenile burrowing owls at this age cannot fly. Juvenile owls began leaving the immediate vicinity of their natal burrows (i.e., entranceway and nearby mound) approximately 21 days after hatching. Because young at this stage were not capable of sustained flight, these first movements were probably accomplished by a combination of walking and flying to nearby *satellite* burrows. Satellite burrows are non-natal burrows used by owls for cover and roosting. The average distance from the natal burrow to the first satellite burrow was 28.9 m ($N = 8$ nests), ranging from around 7 m to over 50 m (Table 2). Most family groups had more than one satellite burrow within their respective natal areas that family members used on different occasions.

We classified the vegetation surrounding roosting owls each day upon which we located them. During the pre-fledging period, radio-tagged owls ($N = 15$) were observed in open grasslands 273 times (39.5%), grasslands with big sagebrush 183 times (26.5%), rock outcrops 141 times (20.4%), along roadsides or fencerows 78 times

(11.3%), in agricultural fields 11 times (1.6%), and in areas with dense big sagebrush 5 times (0.7%; Fig. 5).

Post-fledging Behavior. — Juveniles began flying (i.e., fledged) during the period between mid-June and mid-August (Fig. 4). The earliest that we observed young owls performing sustained flight was 14 June. Juveniles usually abandoned their natal burrows after fledging, but some returned for several days at a time subsequent to attaining the ability to fly.

After fledging, juveniles moved farther away from natal burrows but continued to occupy satellite burrows within their parents' home ranges. Siblings often remained together during this time. For example, three siblings, from the Swan Falls #1 family, roosted together at a burrow located 500 m from their natal burrow two days after departing from their natal area. However, juveniles in other families appeared to move independently of their siblings.

Our observations indicate that adult owls reduced or stopped providing juveniles with food prior to dispersal. In at least three family groups, adults left the nest area before their offspring. In two families, Dairy #2 and Kuna Butte #2, the adult males left several weeks prior the dispersal of their young. At Dairy #3, the adult female left the area before her offspring; the adult male remained in the natal area until mid-October (after the young dispersed) when it appeared to initiate fall migration.

Juveniles initiated post-fledging dispersal movements (>300 m) away from natal areas in late-July and continued into September (Table 5). The dispersal dates of 15 juveniles in 6 families ranged from 20 July - 2 October (mean date of dispersal was 19 August; Table 5). The mean age at the initiation of post-fledging dispersal movements was 88.1 days post-hatching. Dispersing juveniles traveled a mean distance of 1425.9 m from their natal burrows prior to the initiation of fall migration (Table 5). Figure 6 shows dispersal directions for 15 radio-tagged juvenile burrowing owls. The mean direction of dispersal was $153.8^\circ \pm 74.7^\circ$ ($r = 0.145$). The distribution of dispersal directions did not differ significantly from a uniform distribution (Rayleigh's $R = 2.235$, $z = 0.333$, $P > 0.50$); thus, dispersal directions appeared to be random rather than oriented in a specific direction.

After radio-tagged juveniles fledged, during the day they were observed in areas classified as grasslands with some big sagebrush ($N = 33$, 27.8%), open grasslands ($N = 30$, 25.2%), dense big sagebrush ($N = 28$, 23.5%), and rock outcrops ($N = 28$, 23.5%), respectively (Fig. 5). After fledging, we failed to observe the 15 young owls in agricultural fields or along roadsides and fencerows, at least during the day. Young owls were known to use these latter habitats at night, however (pers. observ.). Additionally, owls occupied dense sagebrush areas much more frequently during the post-fledging period than during the pre-fledging period (Fig. 5).

Effects of Food Abundance on Post-fledging Dispersal Movements. — Juvenile burrowing owls with access to supplemental food exhibited post-fledging dispersal

movements later than those with no access to supplemental food (Table 6). Additionally, juveniles with no access to supplemental food moved much farther away from their natal areas than those receiving supplemental food. These results indicate that one factor influencing post-fledging movements in burrowing owls may be the availability of food during the post-fledging period.

Fall Migration

Table 7 summarizes the date of final sighting for juvenile radio-tagged burrowing owls ($N = 15$). It was difficult to discern when post-fledging movements ended and when fall migration movements began for many individuals. However, our observations suggest that many burrowing owls began migrating in mid-September. It was at this time that eight radio-tagged juveniles appeared to leave the study area because we were unable to relocate them, even from the fixed wing airplane during complete censuses of the study area. Prior to their sudden departure, we consistently observed these owls in the same locations for up to several weeks. That is, these owls clearly occupied specific areas after departure from the immediate vicinity of natal burrows. The last owls to leave the study area were two adult males, which remained until 18 October. On 19 October, we conducted our final aerial search of the study area and approximately 200 km² of adjacent habitat. We did not relocate any radio-tagged owls during this survey, and foot surveys after this time located no additional burrowing owls on the area. Based on results of earlier surveys during which we easily detected owls when they were present, had the young owls been in the vicinity, we are confident that we would have detected them during the aerial and foot surveys.

Mortality Factors and Survival Rates

Potential predators of burrowing owls were observed within the study area, including badgers, striped skunks (*Mephitis mephitis*), domestic cats (*Felis* sp.), coyotes (*Canis latrans*), several raptors, and several species of snakes. At least two of six unsuccessful nesting attempts failed because of predation. One of these failures was likely caused by a striped skunk which we observed leaving a nest burrow. The other was caused by an unknown predator that killed at least one nestling, and fatally wounded the adult female which we found dead at another burrow 30 m away. Juvenile owls also suffered mortality from shootings ($N = 1$), collisions with automobiles ($N = 1$), and entanglement in a barbed wire fence ($N = 1$). We also observed a prairie falcon (*Falco mexicanus*) attempt to capture juvenile owls which were standing at the entrance to their burrow. We suspect starvation contributed to the deaths of several nestlings in a family where at least eight young were present (Kuna Butte #6). One young owl (#1204-43616) was noticeably smaller than its siblings and appeared malnourished. On 5 June, this juvenile's leg bands (aluminum band and 3 color bands) were found within a regurgitated burrowing owl pellet at the entrance to the natal burrow. This juvenile was apparently eaten by a family member. We do not know if the juvenile was killed by a sibling or parent and then consumed, or if it died of starvation and was eaten later.

Nonetheless, there apparently was an insufficient supply of food for this large family so that it experienced brood reduction.

We calculated survival rates for both juveniles and adults during the pre-fledging and post-fledging periods. During the pre-fledging period, 27 of 35 young were known to survive (77% survival rate). Only 1 of 26 adults died during the pre-fledging period, giving rise to a 96.2% survival rate for adults during this time. Of the 27 young surviving the pre-fledging period, 25 survived to disperse (92% survival), while no adults died during the post-fledging period (100% survival).

SUMMARY AND CONCLUSIONS

Nest Habitat. — Burrowing owls in our study nested in areas with other burrows, close to roads and agricultural fields, and surrounded by bare ground, short grass, and sparse sagebrush. We found that nests that fledged at least one young had shorter vegetation surrounding them, but the difference only approached statistical significance. A larger study would be required to confirm the effect of vegetation height on reproductive success. Nonetheless, many of these parameters are similar to previously published accounts from other portions of the range of burrowing owls (e.g., Colorado, Plumpton and Lutz 1993b; Saskatchewan, Haug et al. 1993). In contrast, nests in Florida appear to be concentrated in residential and industrial areas (Haug et al. 1993). In a study designed to examine nest-site selection by burrowing owls in southcentral Idaho, Rich (1986) found that in comparison to randomly chosen sites, occupied sites (i.e., those used by nesting owls) had greater cover of cheatgrass brome, had a greater habitat diversity, were lower in elevation, and were more frequently on southerly aspects. According to Rich (1986), sagebrush was also a potentially important habitat feature because many nests were located within 100 m of sagebrush. As did Rich (1986), we found that continuous, dense sagebrush stands were rarely occupied by burrowing owls, at least during the nesting phase of the life cycle. Thus, in southwestern Idaho and throughout their range, burrowing owls use open areas with low vegetation for nesting, provided an adequate supply of burrows in which they can nest is available.

Behavior of Young Owls. — Young burrowing owls appeared at the entrances to their burrows before they were capable of sustained flight, and it was during this time period that we found it easiest to capture many of the young owls on the study area. Noose rods buried at the entrance to burrows were effective in capturing both young and adult owls at burrows. When owlets were around 21 days of age, they frequently left their natal burrows and took up residence at satellite burrows within the home ranges of their parents. The first satellite burrows used by young owls averaged slightly less than 30 m away from the natal burrow. Thus, it follows that if one observes young burrowing owls that are only marginally capable of flight, they are fairly close to the burrow in which they were raised. Young owls became capable of sustained flight beginning in mid-June, at which time they began to move farther away from natal burrows but remained within parental home ranges. It was more